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(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

5.4.6 REACTOR CORE ISOLATION COOLING SYSTEM (BWR)

REVIEW RESPONSIBILITIES

Primary - Reactor Systems Branch (RSB)

Secondary - None

I. AREAS OF REVIEW

The reactor core isolation cooling (RCIC) system in a boiling water reactor (BWR) is a safety system which serves as a standby source of cooling water to provide a limited decay heat removal capability whenever the main feedwater system is isolated from the reactor vessel. Abnormal events which could cause such a situation to arise include an inadvertent isolation of all main steam lines, loss of condenser vacuum, pressure regulator failures, loss of feedwater, and the loss of offsite power. Each of these transients is analyzed in Chapter 15 of the applicant's safety analysis report (SAR). For each of these events, the high pressure part of the emergency core cooling system (ECCS) provides a backup function to the RCIC system. This review of the RCIC is performed to assure conformance with the requirements of General Design Criteria 4, 5, 29, 33, 34 and 54.

The RCIC system consists of a steam-driven turbine-pump unit and associated valves and piping capable of delivering makeup water to the reactor vessel and supplying steam to and removing condensate from the RCIC steam turbine where applicable. Fluid removed from the reactor vessel following a shutdown from power operation is normally made up by the feedwater system, supplemented by inleakage from the control rod drive system. If the feedwater system is inoperable, the RCIC turbine-pump unit starts automatically or is started by the operator from the control room. The water supply for the RCIC system comes from the condensate storage tank, with a secondary supply from the suppression pool.

The review of the RCIC system includes the system design bases, design criteria, description, and the points noted below.

The RSB is responsible for performing the technical review of the RCIC system in the following areas:

1. The piping and instrumentation diagrams are reviewed to determine that the system is capable of performing its intended function and of being preoperationally and operationally tested.

2. The degree of separation of the RCIC system from the high pressure core spray (HPCS) system, or high pressure coolant injection (HPCI) system is reviewed for protection against common mode failure of redundant systems.

3. The process flow diagram is reviewed to confirm that the RCIC system design parameters are consistent with expected pressures, temperatures and flow rates.

4. The complete sequence of operation is reviewed to determine that the system can function as intended and that the system is capable of manual operation.

5. The system is reviewed for compliance with the applicable requirements of NUREG-0737 (Ref. 1).

In addition, the RSB will coordinate other branch evaluations that interface with the overall review of the system as follows: Auxiliary Systems Branch (ASB) reviews the RCIC and HPCI (or HPCS) systems for protection against common mode failures from missiles as part of its primary review responsibility for Standard Review Plan (SRP) Sections 3.5.1.1 and 3.5.1.2. Protection against flooding of RCIC and redundant equipment is reviewed by ASB as part of its primary review responsibility for SRP Section 3.4.1. Protection against damage from pipe whip and jet impingement is reviewed by the Mechanical Engineering Branch (MEB) as part of its primary review responsibility for SRP Sections 3.6.1 and 3.6.2. The Standardization and Special Projects Branch (SSPB) reviews the proposed technical specifications as part of its primary review responsibility for SRP Section 16.0. The Procedures and Systems Review Branch (PSRB) reviews the proposed preoperational and critical startup test programs as part of its primary review responsibility for SRP Section 14.2. The MEB reviews the RCIC system to assure that it has the proper seismic and quality group classification as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2. The RCIC is to be enclosed in a seismic Category I structure or building. The design adequacy of this structure or building is evaluated by the Structural and Geotechnical Engineering Branch (SGEB) as part of its primary review responsibility for SRP Sections 3.3, 3.4, 3.5, 3.7, and 3.8. The Containment Systems Branch (CSB) reviews the RCIC system, as part of its primary review responsibility for SRP Sections 6.2.4 and 6.2.6 to confirm that the design is compatible with the containment system and can be isolated. The Instrumentation and Control Systems Branch (ICSB), as part of its primary review responsibility for SRP Section 7.4, evaluates the adequacy of controls and instrumentation of the RCIC system with regard to the required features of automatic actuation, remote sensing and indication, and remote control. The Power Systems Branch (PSB), as part of its primary review responsibility for SRP Section 8.3, evaluates the adequacy of emergency onsite power, sufficiency of battery capacity, and the use of d-c power only. The MEB, as part of its primary review responsibility for SRP Section 3.9.3, ensures that the design and installation of the RCIC system meet applicable codes and are adequate for its proper functioning. The Equipment Qualification Branch (EQB) reviews RCIC system equipment to determine that it is seismically and environmentally qualified for its intended use as part of its primary review responsibility for SRP Sections 3.10 and 3.11.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

RSB acceptance criteria are based on meeting the relevant requirements of General Design Criteria 4, 5, 29, 33, 34 and 54. Specific criteria to meet the requirements of the above GDCs are as follows:

A. General Design Criteria 4, as related to dynamic effects associated with flow instabilities and loads (e.g., water hammer).

B. General Design Criterion 5 as it relates to structures, systems and components important to safety not being shared among nuclear power units unless it can be demonstrated that sharing will not impair its ability to perform its safety function.

C. General Design Criterion 29 as it relates to the system being designed to have an extremely high probability of performing its safety function in the event of anticipated operational occurrences.

D. General Design Criterion 33 as it relates to the system capability to provide reactor coolant makeup for protection against small breaks in the reactor coolant pressure boundary so the fuel design limits are not exceeded.

E. General Design Criterion 34 as it relates to the system design being capable of removing fission product decay heat and other residual heat from the reactor core to preclude fuel damage or reactor coolant pressure boundary overpressurization.

F. General Design Criterion 54 as it relates to piping systems penetrating primary containment being provided with leak detection and isolation capabilities.

Specific acceptance criteria, Regulatory Guides, and Task Action Plan items that provide information, recommendations and guidance and in general describe a basis acceptable to the staff that may be used to implement the requirements of the Commission regulations identified above are as follows:

1. The general objective of the review is to determine that the RCIC system, in conjunction with the HPCS (or HPCI) system, the safety/relief valves, and the suppression pool cooling mode of the residual heat removal system meets the requirements of General Design Criterion 34 (Ref. 2) by providing the capability for decay heat removal to allow complete shutdown of the reactor under conditions requiring its use. It must maintain the reactor water inventory above the top of the active fuel until the reactor is depressurized sufficiently to permit operation of the low pressure

cooling systems. The RCIC system, in conjunction with the HPCS (or HPCI) system, the safety/relief valves, and the suppression pool cooling mode of the RHR system must be capable of removing fission product decay heat and other residual heat from the reactor core following shutdown so as to preclude fuel damage or reactor coolant pressure boundary overpressurization. Since RCIC in conjunction with HPCS (or HPCI) is used to provide makeup inventory in some modes of residual heat removal, these systems should jointly meet the guidelines of BTP RSB 5-1, attached to SRP Section 5.4.7.

2. The RCIC system is also used to supply reactor coolant makeup for small leaks. Accordingly, the systems must meet the requirements of General Design Criterion 33 (Ref. 4) in this regard.

3. Historically, credit has been taken for RCIC system capability to mitigate the consequences of certain abnormal events; however, since the cooling function is redundant to the HPCI or HPCS system, the RCIC system itself is not required to meet the single failure criterion, but in conjunction with HPCS (or HPCI) must satisfy the single failure criterion in this regard. In addition, the RCIC system is to perform its function without the availability of any a-c power per the requirements of General Design Criterion 34 (Ref. 2), and in conjunction with HPCS (or HPCI) must be designed to assure an extremely high probability of accomplishing its safety function as required by General Design Criterion 29 (Ref. 6).

4. As a system which must respond to certain abnormal events, the RCIC system must be designed to seismic Category I standards (discussed in SRP Section 3.2.1) and must not be shared among nuclear power units except as permitted by General Design Criterion 5 (Ref. 7).

5. The RCIC and HPCS (or HPCI) systems must be protected against natural phenomena, external or internal missiles, pipe whip, and jet impingement forces so that such events cannot fail both systems simultaneously. Acceptance criteria for these are discussed in SRP Sections 3.3.1 through 3.6.2. Acceptance criteria for RCIC instrumentation are described in SRP Section 7.4.

6. The RCIC system must meet the requirements of General Design Criterion 54 (Ref. 8) with regard to leak detection and isolation provisions for lines passing through the primary containment. Other containment isolation criteria for RCIC are described in SRP Sections 6.2.4 and 6.2.6.

7. The RCIC system must meet the recommendations of Task Action Plan items II.K.1.22, II.K.3.13, II.K.3.15, II.K.3.22, II.K.3.24, and III.D.1.1 of NUREG-0737 (Ref. 1) and NUREG-0718 (Ref. 11) with regard to actions needed for operation, system initiation setpoint and automatic restart capability, break detection provisions, automatic suction switchover to the suppression pool, adequacy of space cooling, and leakage minimization, respectively.

8. If the RCIC system is used to control or mitigate the consequences of an accident, either by itself or as a backup to another system, it must meet the requirements of an engineered safety feature. The RCIC system must

meet the guidelines of Regulatory Guide 1.1 (Ref. 9) regarding net positive suction head.

9. In order to meet the requirements of General Design criterion 4 (Ref. 12) design features and operating procedures, designed to prevent damaging water hammer due-to such mechanisms as voided discharge lines, steam bubble collapse and water entrainment in steam lines, shall be provided.

III. REVIEW PROCEDURES

The procedures below are used during the construction permit (CP) review to assure that the design criteria and bases and the preliminary design as set forth in the preliminary safety analysis report meet the acceptance criteria given in subsection II.

For the operating license (OL) review, the procedures are used to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report. The OL review also includes the proposed technical specifications, to assure that they are adequate in regard to limiting conditions of operation and periodic surveillance testing.

1. Using the RCIC operating requirements specified in SAR Section 5.4.6 and Chapter 15, the reviewer confirms that the RCIC system can maintain coolant inventory in the reactor vessel to keep the core covered and assure cladding integrity. This determination is based on engineering judgment and independent calculations (where deemed necessary), using information as specified in steps 2 and 3 below. The reviewer consults with the CPB to assure that the decay heat loads used in the RCIC analyses are applicable and suitably conservative.

2. Using the description given in Section 5.4.6 of the SAR, including component lists and performance specifications, the reviewer determines that the RCIC system piping and instrumentation are such as to allow the system to operate as intended. This is accomplished by reviewing the piping and instrumentation diagrams to confirm that piping arrangements permit the required flow paths to be achieved and that sufficient process sensors are available to measure and transmit required information.

3. Using the comparison tables of SAR Section 1.3, the RCIC system is compared to designs and capacities of such systems in similar plants to see that there are no unexplained departures from previously reviewed plants. Where possible, comparisons should be made with actual performance data from similar systems in operating plants.

4. The reviewer checks the piping and instrumentation diagrams and equipment layout drawings for the RCIC and HPCS (or HPCI) systems to see that the systems are physically separated and can function independently.

5. The reviewer examines the system design in SAR Section 5.4.6 to verify that the capability for automatic switchover of suction from the condensate storage tank to the suppression pool has been provided per the requirements of item II.K.3.22 of NUREGs-0737 and 0718 (Ref. 1 and 11). The reviewer also judges whether adequate control and monitoring infor-

mation is available to allow the operator to actuate the system manually or to realign the RCIC system manually within the time allowed (i.e., change the RCIC system suction from the condensate storage tank to the suppression pool, or to the steam condensing mode of the residual heat removal system).

6. The reviewer contacts ICSB to confirm that automatic actuation and remote-manual valve controls are capable of performing the functions required and that sensor and monitoring provisions are adequate. The instrumentation and controls of the RCIC system, in conjunction with the HPCS (or HPCI) system are to have sufficient redundancy to satisfy the single failure criterion.

7. The reviewer contacts PSB to ascertain that the RCIC system operation is not dependent on a-c power sources, and that there is sufficient battery capability to permit operation of the RCIC for a period of two hours without the availability of a-c power.

8. The reviewer checks with MEB to verify that essential RCIC system components are designated seismic Category I.

9. The reviewer contacts PSRB to verify that the applicant's proposed preoperational and initial startup test programs are in compliance with Regulatory Guide 1.68 (Ref. 10). At the OL stage, the reviewer confirms with PSRB that sufficient information is provided by the applicant to identify the test objectives, methods of testing, and test acceptance criteria (see par. C.2.b of Regulatory Guide 1.68). PSRB also verifies that the proposed test programs will provide reasonable assurance that the RCIC system will perform its safety function. As an alternative to this detailed evaluation, the reviewer may compare the RCIC system design to that of previously reviewed plants. If the design is essentially identical and if the proposed test programs are essentially the same, the reviewer may conclude that the proposed test programs are adequate for the RCIC system. If the RCIC system differs significantly from that of previously reviewed designs, the impact of the proposed changes on the required preoperational and initial startup testing programs are reviewed at the CP stage. This effort should particularly evaluate the need for any special design features required to perform acceptable test programs.

10. The SSPB is contacted in regard to the proposed plant technical specifications to:

    a. Confirm the suitability of the limiting conditions of operation, including the proposed time limits and reactor operating restrictions for periods when system equipment is inoperable due to repairs and maintenance.

    b. Verify that the frequency and scope of periodic surveillance testing is adequate.

11. The reviewer confirms that the RCIC is housed in a structure whose design and design criteria have been reviewed by other branches (i.e., ASB, SGEB, MEB) to assure that it provides adequate protection against wind, tornadoes, floods, and missiles, as appropriate.

12. Upon request from the primary reviewer, other branches will provide input for the areas of review stated in subsection I. The primary reviewer obtains and uses such input as required to assure that this review procedure is complete.

13. The reviewer checks the automatic and manual actions necessary for proper functioning of the RCIC system (in conjunction with the HPCS or HPCI, the safety relief valves and the suppression pool cooling mode of RHR) for completeness and practicality when used for residual heat removal per the requirements of item II.K.1.22 of NUREGs-0737 and 0178 (Ref. 1 and 11).

14. The reviewer checks the RCIC system break detection provisions to see that the system is protected against spurious trip signals per the requirements of item II.K.3.15 of NUREGs-0737 and 0718 (Ref. 1 and 11).

15. The reviewer confirms, in conjunction with ASB as necessary, that the RCIC system can withstand a loss of offsite power to its support systems, including space coolers, for at least two hours per the requirement of item II.K.3.24 of NUREGs-0737 and 0718 (Ref. 1 and 11).

16. The reviewer confirms per the requirements of item II.K.3.13 of NUREGs-0737 and 0178 (Ref. 1 and 11) that analyses have been provided or referenced to determine the need to separate the RCIC and the HPCS (or HPCI) initiation levels. Based on these study results, the reviewer checks the RCIC design for appropriate provisions. In addition, the reviewer checks to see that automatic restart capability is provided for RCIC.

17. The reviewer checks (by calculation as necessary) to see that adequate net positive suction head is available for RCIC suction from all potential sources (i.e., condensate storage tank, suppression pool, or RHR steam condensing mode discharge).

18. The reviewer examines the RCIC in conjunction with the HPCS or HPCI, the safety/relief valves and the suppression pool cooling mode of RHR for conformance to the recommendations of BTP RSB 5-1 to SRP Section 5.4.7 regarding residual heat removal.

19. The RCIC system is reviewed to evaluate the adequacy of design features that have been provided to prevent damaging water (steam) hammer due to such mechanisms as voided discharge lines, water entrainment and steam bubble collapse. If the normal water supply is above the discharge lines, voided lines are prevented by proper vent location and filling and venting procedures. The vents should be located for ease of operation and testing on a periodic basis. If the normal alignment of the suction valves is to a source below the highest level of the pump discharge lines (e.g., the suppression pool,) back leakage through the pump discharge check valves will result in line voiding. Proper vent location and filling and venting procedures are still needed. In addition, a special keep-full system with appropriate alarms is needed to supply water to the discharge lines at sufficiently high pressure to prevent voiding. Operating and maintenance procedures shall be reviewed by the applicant to assure that adequate measures are taken to avoid water hammer due to voided line conditions.

The RCIC system uses a steam-driven turbine. Typical design features for the steam supply line include (a) drain pots, (b) sloped lines, and (c) limitations on opening and closing sequences and-seal-ins for manual operation of the isolation valves to preclude introducing water slugs into the line. The turbine exhaust line features include sloped lines and vacuum breakers.

IV. EVALUATION FINDINGS

The reviewer verifies that the SAR contains sufficient information and his review supports the following kinds of statements and conclusions, which should be included in the staff's safety evaluation report:

> The reactor core isolation cooling (RCIC) system includes the piping, valves, pumps, turbines, instrumentation, and controls used to maintain water inventory in the reactor vessel whenever it is isolated from the main feedwater system. Certain engineered safety features (HPCS or HPCI) provide a redundant backup for this function. The scope of review of the RCIC system for the ________plant included piping and instrumentation diagrams, equipment layout drawings, and functional specifications for essential components. The review has included the applicant's proposed design criteria and design bases for the RCIC system, his analysis of the adequacy of the criteria and bases, and the conformance of the design to these criteria and bases.

The staff concludes that the reactor core isolation cooling system design is acceptable and meets the requirements of General Design Criteria 4, 5, 29, 33, 34 and 54. This conclusion is based on the following:

1. The applicant has met the requirements of (cite Reg.) with respect to (state limits of review) by: (Use one or more of the following as applicable)

   a. meeting the regulatory position in Regulatory Guide ________,

   b. providing and meeting an alternative method to the regulatory position in Regulatory Guide _______, that the staff has reviewed and found to be acceptable,

   c. meeting the regulatory position in BTP___________

   d. The calculational method used by the applicant for (state) has been previously reviewed by the staff and found acceptable; the staff has reviewed the key parameters in this case and found them to be suitably conservative.

   e. The applicant has met the requirements of (industry standard - number and title) that has been reviewed by the staff and determined to be appropriate for this application.

2. Repeat the above discussion for each GDC listed.

In addition, conformance with General Design Criterion 55, 56, and 57 regarding containment isolation is discussed in Section 6.2 of this report. Conformance with General Design Criterion 2 and 4 for protection against natural phenomena, environmental hazards and potential missiles is discussed in Sections 3.3 through 3.6 of this report.

The RCIC and HPCS (or HPCI) systems, in conjunction with the safety/relief valves and the suppression pool cooling mode of the residual heat removal system, have been found capable of removing core decay heat following feedwater system isolation and reactor shutdown so that sufficient coolant inventory is maintained in the reactor vessel to keep the core covered and ensure cladding integrity. This capability has been found to be available even with a loss of offsite power and with a single active failure.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides, NUREGs and implementation of acceptance criterion subsections II.A and II.9 is as follows:

(a) Operating plants and OL applicants need not comply with the provisions of this revision.

(b) CP applicants will be required to comply with the provisions of this revision.

VI. REFERENCES

1. NUREG-0737, "Clarifiation of TMI Action Plan Requirements," November 1980.
2. 10 CFR Part 50, Appendix A, General Design Criterion 34, "Residual Heat Removal."
3. Branch Technical Position RSB 5-1, "Design Requirements of the Residual Heat Removal System," attached to SRP Section 5.4.7.
4. 10 CFR Part 50, Appendix A, General Design Criterion 33, "Reactor Coolant Makeup."
5. Regulatory Guide 1.53, "Single Failure Criterion."
6. 10 CFR Part 50, Appendix A, General Design Criterion 29, "Protection Against Anticipated Operational Occurrences."
7. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems, and Components."

8. 10 CFR Part 50, Appendix A, General Design Criterion 54, "Piping Systems Penetrating Containment."

9. Regulatory Guide 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Systems."

10. Regulatory Guide 1.68, "Initial Test Programs for Water-Cooled Reactor Power Plants."

11. NUREG-0718, "Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License."

12. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Missile Design Bases".